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# Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Relation of Precision Mechanisms to Petroleum

PUBLISHED BY

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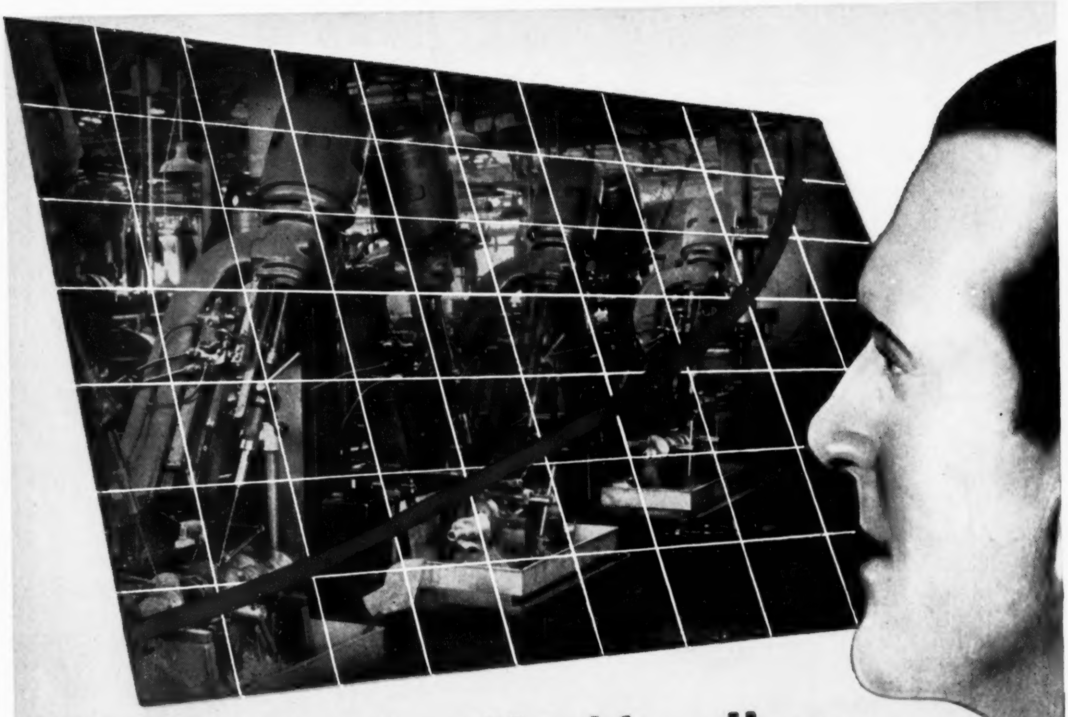

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LUBRICATION

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# Relation of Precision Mechanisms to Petroleum

## *Cutting, Grinding and Lubrication*

SOME remarkable progress has been made during recent years in the perfection of precision mechanisms. This has made it practicable to go to successively lower tolerances as surface finishes have been improved. Then, as the developments progressed, it was found that machinery could be run at higher speeds, that certain types of bearings and gears would carry higher loads.

A justifiable tribute was accorded the machine designer and metallurgist—their contributions were so obvious. The petroleum chemist, however, must not be overlooked. His research made possible the development of the oils required for cutting, grinding and lapping of these precision parts and the lubricants required later for their subsequent protection in service. Without petroleum, machinery would hardly have passed beyond the tallow pot stage.

**Industry today is concerned with the production value of machinery. The investment value is secondary. So the war effort cannot wait to run-in bearings or gears—their running surfaces must be developed during the manufacturing procedure. This means that metal cutting and surface finishing operations must be planned to anticipate subsequent operating conditions which have long since passed from the 40-hour week to full time service. Labor must have time out, machinery cannot. Lubrication must protect the working mechanisms under these operating conditions, so the petroleum chemist is more important than ever in perfecting improved lubricants which will enable the war-production industries to function at top speed.**

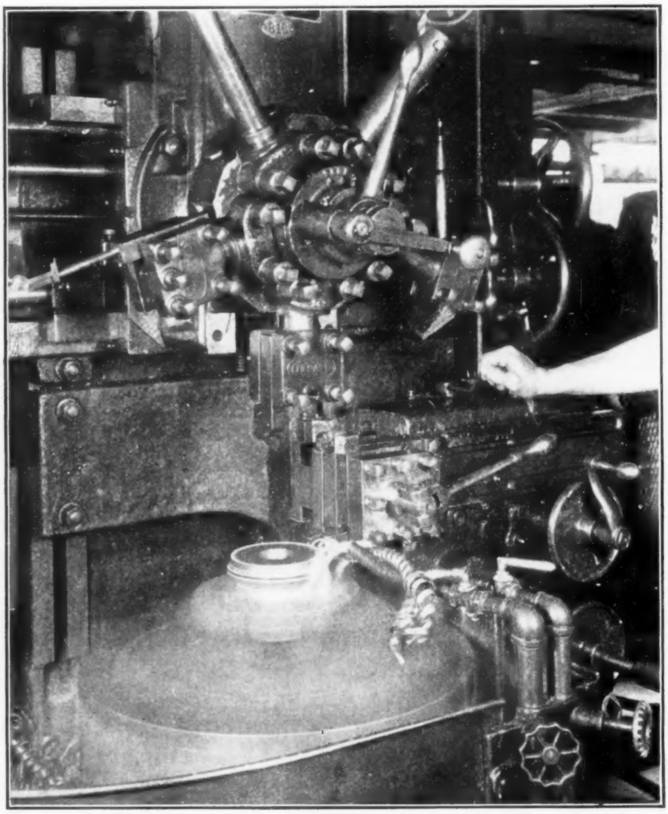
In discussing precision mechanisms it is necessary to consider their production as well as their operation. Obviously, it is impossible to cover each and every type in detail, nor is it necessary, for the basic principles are so fundamentally alike regardless of the duty involved.

### METAL CUTTING

In considering protection we must start with the rough cutting of the base stock, primarily machine steel which has been alloyed by the metallurgist to obtain certain hardness characteristics as indicated by the Brinell or Rockwell scales. Cutting of such steels is not an easy matter; cutting tools dull rapidly. They may be distorted as the chips are formed and sometimes they may break. As rapid and effectual cutting is the secret of mass production, it is a basic necessity.

Accordingly, the petroleum chemist planned his research to develop cutting oils which

would give the required protection to the cutting tools. He had to go way beyond the conventional lard plus mineral oil compounds which had served so well when machinists worked with soft steels and hundredths of an inch tolerances. The newer types of hardened tool steels developed far more heat in cutting, even to such an extent that welding of the chips to the cutting tool might occur. It is one of the primary functions of the cutting oil to remove this heat, but at the same time the oil has to lubricate, otherwise fresh, dry metallic surfaces might be exposed. Such a condition is the forerunner of welding.



*Courtesy of The Bullard Company*

Fig. 1—Close-up of a Bullard vertical turret lathe showing action of the cutting fluid as it flows over the cutting tool and part being machined.

So, we are confronted with a heat transfer problem. On ordinary work a cutting oil of conventional characteristics can be depended upon to reduce this heat within safe limits. Frictional heat, however, may become extreme when deep cutting or lengthy boring is done. Here the cut and tool may be so inaccessible that merely sluicing the work with oil will be ineffectual. Then it becomes necessary to provide sufficient volume of the cutting fluid to cover the working area adequately. This increases the rate of cooling; the flood of oil also washes the chips away from the cut before they can accumulate and become a detriment.

This is one of the primary reasons why pressure lubrication and cooling of cutting tools has been so widely adopted. Pressure control also means that the flow can be regulated and controlled according to the nature and type of cut.

Expansion of the parts being machined must also be considered. Unless the cutting fluid is functioning effectively, the work will become heated during the cutting process. Under such conditions should parts be cut to size before being allowed to cool they would be undersized when removed from the machine. Obviously, to allow for atmospheric cooling before the final measurement is taken in order to develop the proper size, would slow up production and by so doing would increase the cost of the part.

## How The Study Was Approached

Inasmuch as heat transmission was the most obvious function of a cutting oil, it was at first regarded by many as the most important duty. More recently, however, opinions have differed and some of the more progressive operators regard lubrication as of equal importance.

During the earlier experimental stages through which the machine tool industry naturally passed, water was used for the purpose of heat reduction. Water was cheap, easily handled and admirable for its heat abstracting characteristics. But water causes rust. Therefore, the addition of soda was adopted, for such mixtures apparently reduced the extent to which corrosion and rust formation occurred, and afforded a certain amount of lubrication. Still, their chief advantage was their cooling ability and relatively low cost.

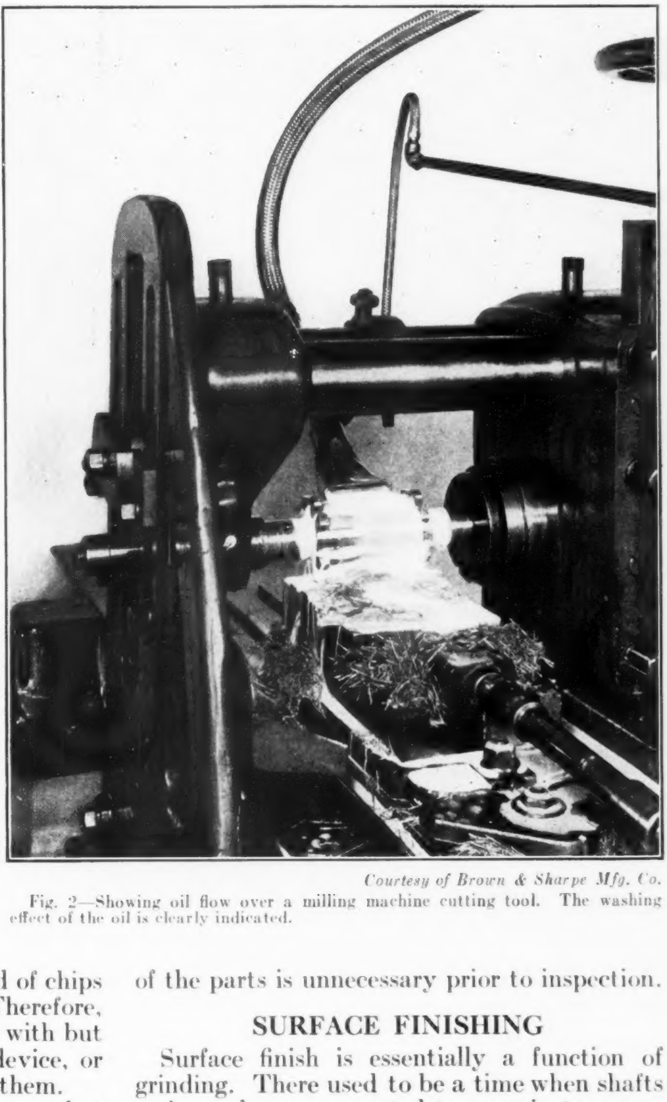
Soda-wash solutions are still used in some grinding operations, both work and grinding wheel being flooded continually. They are detrimental, however, in that they not only remove paint from any parts of the machine with which they come in contact, but also tend later to cut the lubricant from any bearings or other wearing parts with which they come in contact, thus being the potential cause of lubricating difficulties.

Water and soda solutions, however, are but poor makeshifts in the reduction of solid or metallic friction. They may serve all very well in the removal of heat, but their lubricating and load-carrying ability is far less than that of petroleum oils. The continued occurrence of solid friction generates heat. Water or soda-wash solutions in turn remove this heat from tool and work if applied in sufficient volume, but friction usually continues. As a result, additional power must be consumed to overcome this friction, provided production is not allowed to suffer. Any reduction of this friction could be expected to lead to greater production, increased tool life and a decrease in operating costs due to improved cutting and higher cutting speeds.

So, the petroleum chemist rightfully concluded that lubrication was entitled to consideration. This included study of soluble oils, lard-soluble oils, mineral oil compounds and later a variety of other additive materials.

Soluble oils are most effective coolants, and on certain types of grinding work today they are a practical necessity. In such products water is the essential component, therefore, it is still able to serve its original purpose as a tool coolant. In addition, the percentage of mineral oil, etc., which such a compound contains, is claimed to give the requisite amount of lubrication on work where tool cooling is the essential factor. Due to the high water ratio, these products are inexpensive, easy to mix, and by reason of their low viscosity, readily freed of chips and other solid foreign matter. Therefore, they can be used over and over again with but the necessity for a simple straining device, or centrifuging to properly recondition them.

Certain authorities contend, however, that this matter of cooling is, after all, but a question of volume rather than any relative cooling ability. In other words, a lard or mineral oil, or a mixture of these two, or the use of a sulfurized mineral oil, could be expected to give the requisite results if supplied in sufficient volume and properly cooled and clarified after each circulation. In addition the important feature of lubrication would be amply taken care of. Later the matter of visibility was studied resulting in our modern transparent cutting oils. The more transparent the oil the better can the operator see his work. Normally this is most advantageous where control by the operator is necessary and where no complete cycle of operation is involved; inspection is also facilitated, at reduced cost, for washing of the parts is unnecessary prior to inspection.



*Courtesy of Brown & Sharpe Mfg. Co.*

Fig. 2—Showing oil flow over a milling machine cutting tool. The washing effect of the oil is clearly indicated.

## SURFACE FINISHING

Surface finish is essentially a function of grinding. There used to be a time when shafts or journals were expected to wear in to a running fit with their respective bearings; proper running mesh of gear teeth was also expected to develop during the running-in period. This took time. Also, it required that the machinery be run at reduced speed and at reduced power or production output. So, full return on the investment did not begin until the parts in question had been run in to a flexible running fit. Then we thought of the dollar value of the investment.

Today we are concerned with the production value. So, industry cannot wait to run in

machinery—the running surface must be developed during the manufacturing procedure. This is accomplished by careful grinding and polishing in order to smooth down those microscopic high spots which would otherwise require flattening in service at the expense of power consumption, loss of productive efficiency and overloading the lubricating film.

Precision finishing today requires that the grinding process be carried out by grinding wheels rotating at comparatively high surface speeds. While the wheel is in contact with the work a generous flood of light petroleum soluble oil mixed with water is directed across the contact surfaces. In grinding the chief function of the cutting fluid is cooling.

The petroleum chemist has given very careful attention to the developments of emulsifiable mineral oil compounds for this work. If the problem was confined only to cooling, i.e., heat transfer, water would be the most effectual material to use. But we must also consider protection of the surfaces of the metals under treatment. Water alone would be a partner with air in causing rust. Freshly cut steels are most susceptible to rusting if there has been no chance for them to be "wet" with a protective film of petroleum oil.

So, the chemist and tool operator must sacrifice some cooling ability by adding a suitable mineral oil compound which will form a permanent emulsion with water and serve as a rust-preventive on the surfaces of the work after grinding is completed.

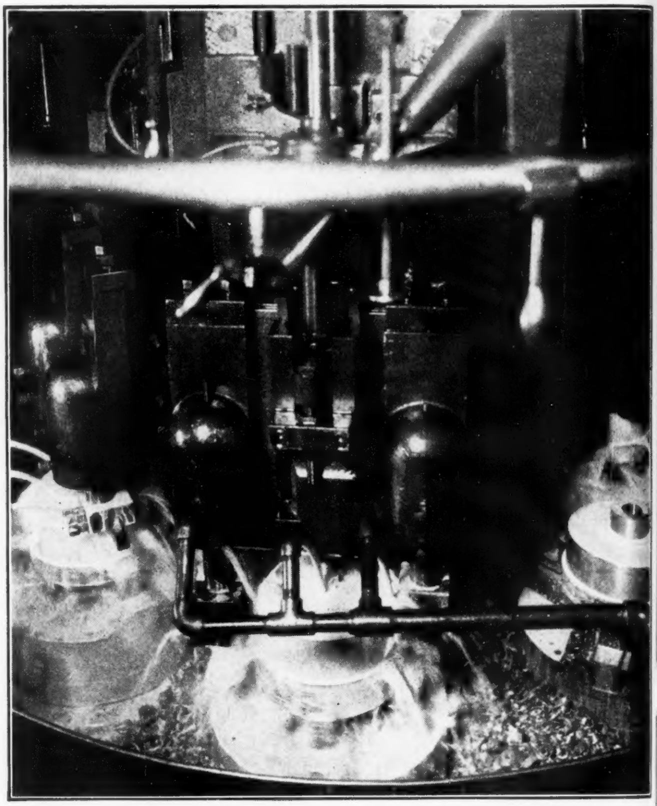
Soluble oil solutions are made by diluting the prepared material with from ten to fifty parts of water. The ratio depends upon the hardness and machinability of the material to be ground. The resultant emulsion must be permanent and stable in order to develop a covering film which will protect the worked surface adequately against rust. Even spreading is most important; should there be uneven dispersion of the oil particles through the emulsion, wherever water might predominate rust spots may appear on the finished work.

A rancid odor is regarded as an indication of instability. With some products separation may be so sharp as to be visible. With others, separation may occur at the time of reconditioning.

## What Constitutes A Good Soluble Oil For Grinding

Stable emulsification with water

Uniform dispersion of oil particles in the grinding mixture



*Courtesy of The Bullard Company*

Fig. 3—A Bullard 6-spindle type "D" Mult-au-matic machine on short run work. Here again, note the washing and cooling effect of the cutting oil.

Ability to protect steel surfaces against rust

Long wheel life, long periods between wheel dressing

Ability to keep grinding wheels from loading up with metallic particles

Ability to separate readily from foreign matter but retain its own original composition when centrifuged

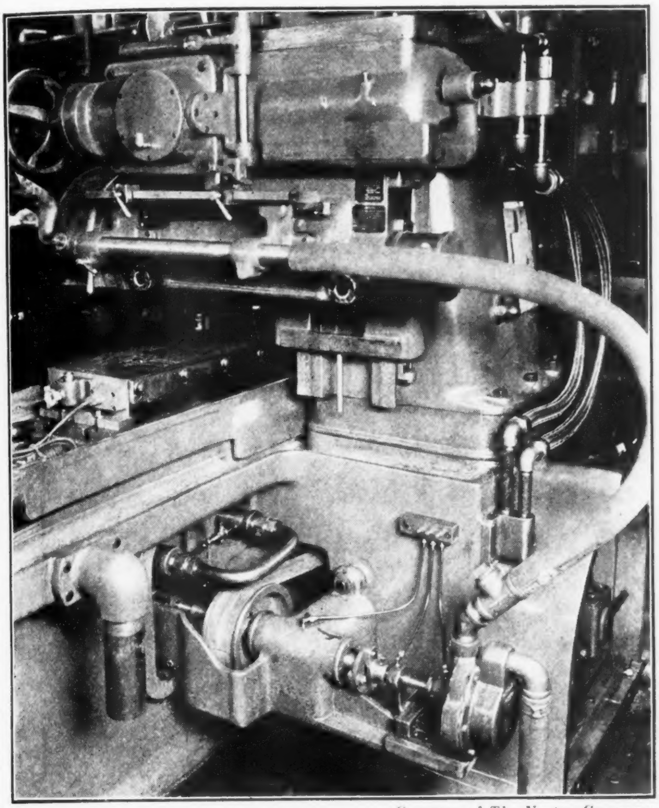
## Indications Of An Unsuitable Soluble Oil

Rancid odor

Inability to emulsify permanently with water

Rust spotting of finished surfaces

Surface finish is materially affected by the volume of cutting fluid delivered to the grinding wheel. A considerable volume gives best results due to effective cooling. Volume is also insurance against possible dry cutting and



*Courtesy of The Norton Company*

Fig. 4—Part of the lubricating system of a Norton grinder, showing certain of the oil leads near the base. Automatic lubrication is a feature of this machine.

premature loading of the grinding wheel. Dry cutting may result in rust spots; a "loaded" wheel tends to produce a finished surface which looks irregular or burnt.

The relative hardness of the water will also be a factor. Due to the electrolytic nature of the salts which cause hardness of water, it is necessary to take special precautions in the manufacture of soluble oils for service with hard water, to prevent breaking of the emulsion.

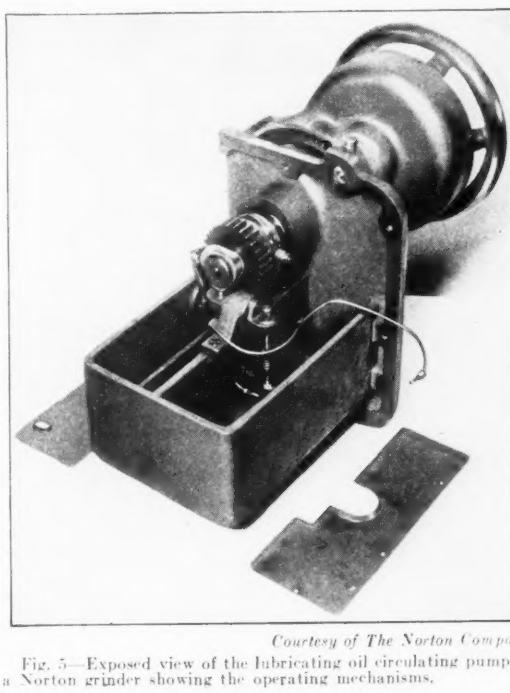
## LUBRICATION OF PRECISION SURFACES

All this study of metal cutting, grinding, polishing and the perfection of cutting and soluble oils was undertaken with one primary objective—speed! To attain this objective, the speed of grinding had first to be increased for speed is one of the essentials of successful grinding. So, before the grinding machine could produce precision mechanisms which would go to make up a high-speed automotive engine, centrifuge or supercharger, the bearings and turning parts of the grinding machine itself had to be perfected.

Fortunately this was all planned several years ago and most of the research done when time permitted careful study. The result has been our present-day precision finishes which, within reasonable limits promote more dependable lubrication. During this transition and period of research, bearing clearances have been reduced 25% below what they were originally.

While research in the field of fluid and boundary lubrication proved that the effect of friction on power consumption can be materially reduced by improving the smoothness of the metallic surfaces of the moving parts, there were limitations, of course, as some investigators learned when they carried their polishing operations too far. Then it was found advisable to purposely hone or roughen the surfaces in order to facilitate lubrication-service.

So perfect finish of a bearing surface is an ideal which should not be approached too closely. The degree of smoothness should be just sufficient to develop the maximum load-carrying capacity. In other words, one should strive to reduce the high spots but not attempt to entirely eliminate the depressions. They provide factors of safety in the



*Courtesy of The Norton Company*

Fig. 5—Exposed view of the lubricating oil circulating pump of a Norton grinder showing the operating mechanisms.

form of minutely shallow oil pockets which present a reserve of oil supply to prevent incipient scoring should any abnormal condition develop. Laboratory research has proved that by extremely careful workmanship it is possible to develop a difference in level between the top of a peak and the bottom of a depression or valley of about two-millionths of an inch. Even this minute distance is still over twenty times the length of an average molecule of oil.

In studying the lubrication of high-speed mechanisms, one must consider the potential possibility of considerable temperature rise at points of minimum clearance where the lubricating films will normally be under fairly high pressure. Breakdown of the oil film at any such points might readily lead to impaired lubrication and subsequent abrasion of the contact surfaces.

As higher speeds are encountered, lubrication by means of more fluid or lighter viscosity lubricants becomes advisable in the interest of reducing drag, loss of power and increase in film temperatures due to internal friction between the component molecules of the lubricant.

Where speed alone is considered, it will generally be practicable from a lubricating point of view, to vary the viscosity or lubricant body inversely with the speed. In other words, for high speed conditions a comparatively light bodied lubricant can be used. Lower speeds will require a heavier product. The reason for this is that the higher the speed the greater will be the degree to which the lubricant will be drawn into the clearance spaces by capillary action.

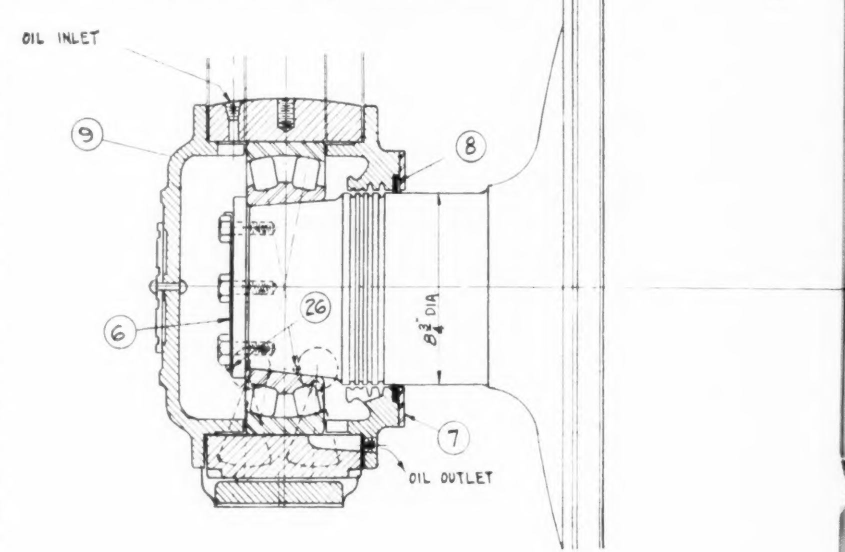



Fig. 6—Showing the dryer bearing arrangement for a high speed paper machine. Note the applicati[...]ral rol[...] direct oil flow to obviate pockets which might tend to accumulate non-lubricating foreign matter. Par[...] indic[...] locking plate for the bearing on the tending side. Note oil inlets and outlets.

The development of a constant film of lubricant within the bearing clearance space, however, will of course be contingent upon the extent to which automatic lubrication is maintained. If oil is delivered by means of a drip feed oiler, wherein the principle is to supply just enough oil to maintain lubrication, increase in speed may result in impaired lubrication unless the rate of drip of oil is increased.

## The Advantage of Flood Lubrication

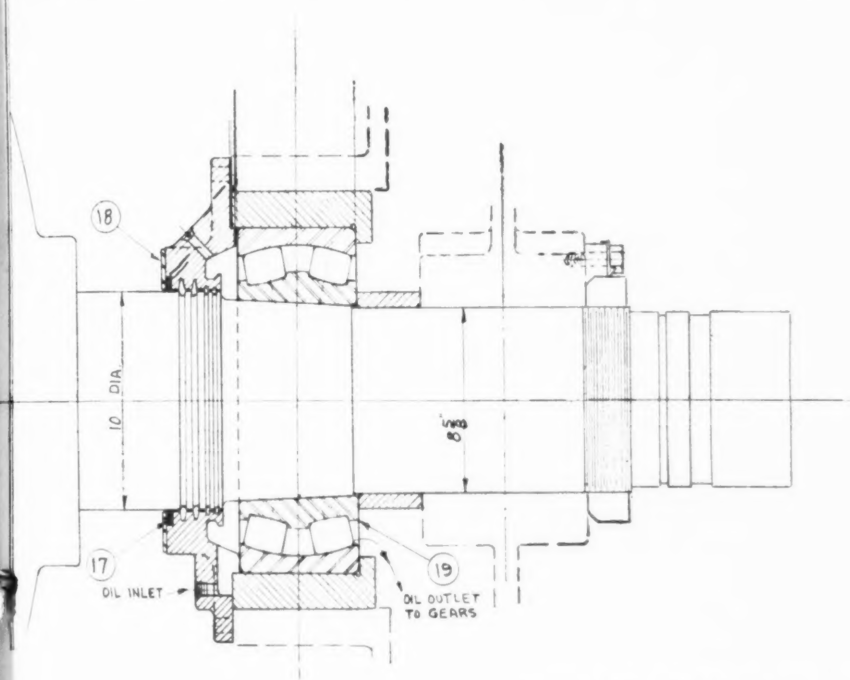
Where automatic force feed lubrication is involved, more oil is normally delivered than is required to maintain lubrication. This type of lubrication will tend also to materially resist the effects of pressure. This is admirably illustrated by the lubricating system of the average pressure-oiled steam turbine bearing. Here, although comparatively high speeds may be involved and bearing pressures may be fairly high, if the oil is delivered under from 8 to 15 pounds pressure a product of as low a viscosity as 140 seconds Saybolt at 100 degrees Fahr., will maintain adequate lubrication and insure protection of the bearings.

## On The Grinding Machine

As the process of grinding finalizes the development of surface finish, it is fitting to review some of the features related to lubrication of machine parts as differentiated from lubrication and cooling in the process of cutting.

As already noted we are dealing with high speed conditions, for surface finish is best controlled by high-speed cutting. Accuracy and

rigidity are other requisites. All these features are characteristic of the modern grinding machine when it goes into production, being the result of cooperation of the machine designer and tool builder. The continued maintenance of speed, rigidity and accuracy, however, becomes the responsibility of the operating engineer and lubrication specialist; upon lubrication will depend the ability to produce maximum results with minimum power requirements.




*Courtesy of The Pusey & Jones Corporation*

...l roller bearings on both the tending and drive side. Of particular interest are the provisions made for ... indicate retaining rings and oil retainer; 9 and 19 show the roller bearings; 22 is the dryer drum; and 6 is a

## Cleanliness a Factor

Flood lubrication by means of oil circulation insures, perhaps, the greatest degree of operating cleanliness possible of attainment, for in addition to serving as a lubricant and coolant the oil will usually wash the entire system free of any accumulations of foreign matter. It is essential, however, that there be an ample quantity of oil in the system and sufficient volume in the reservoir to allow for precipitation or settling out of the majority of any foreign matter which may have been taken up during circulation.

## Minimum Of Attention Required

Another advantage pertinent to such a system is that a minimum of attention is required, and normally but little adjustment. Even so, there usually will be provision for same, a suitable valve being installed in the bearing cap or at some other accessible point. On grinding machines, where oil circulation adjustment is provided for in the bearing cap, an observation window or glass located in front of the bearing enables the operator to note his oil flow at all times.

# FLUSHING AND CLEANING OF BEARINGS

In order to insure the maximum of protection from any lubricant applied to precision machinery it is absolutely essential to keep the lubricating system as free from foreign matter as is consistently possible, according to the operating conditions and bearing construction.

There is always a possibility of entrance of impurities especially where bearings may not be properly sealed. It is a matter of decided importance for we can realize that continued churning of abrasive foreign matter with oil and its passage through plain bearing clearance spaces or in intimate contact with highly polished balls and raceways will ultimately prove the ruination of spindle or main drive bearings and their respective elements.

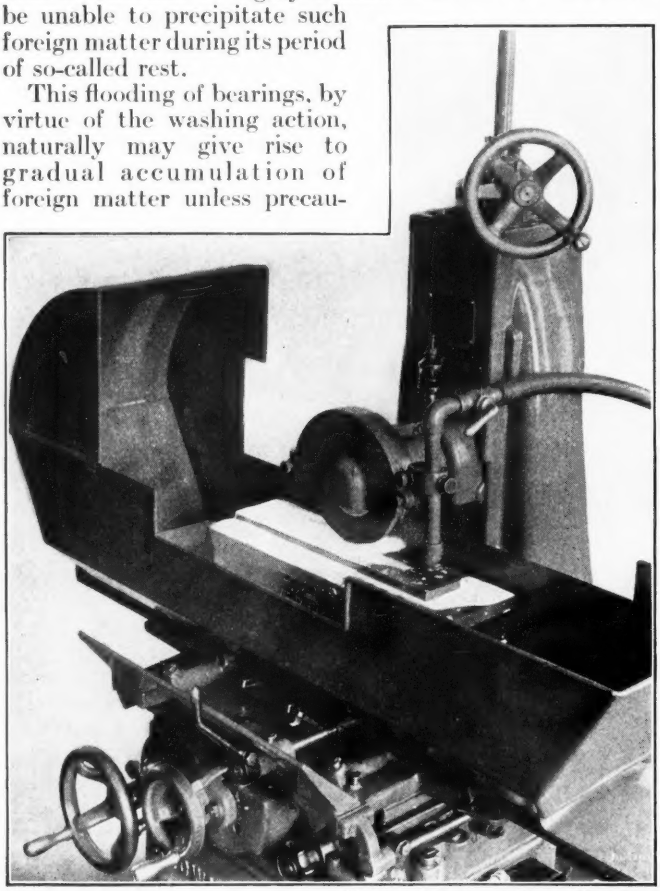
## Sealing Of Bearings Not Always Practicable

In view of the fact that it is not always possible to effect the requisite degree of sealing or to depend upon the seal being in good working order at all times, precision machine bearing lubricating systems should be flushed and cleaned at periodic intervals. The frequency will, of course, depend upon the design of the bearing, the type of seal, the lubricant used and the extent to which dust and dirt are present.

Circulating oiling affords a continuous flushing action in that the flood of oil which is constantly passing through the bearing clearances

tends to wash out any grit, dirt, dust or metallic particles that may have gained entry. On the grinding machine this is assisted by grooving the spindle. As a result, wear is reduced to a minimum, just as long as the oil in the system does not become so highly contaminated as to be unable to precipitate such foreign matter during its period of so-called rest.

This flooding of bearings, by virtue of the washing action, naturally may give rise to gradual accumulation of foreign matter unless precautions are taken, therefore the condition of the oil should be carefully watched and the system drained as soon as any excess of dirt becomes apparent.



*Courtesy of Brown & Sharpe Mfg. Co.*

Fig. 7—Grinding with a Brown & Sharpe machine. Note lubricator fittings on the spindle shaft; also provisions for hand oiling of various of the turning mechanisms below the grinding table.

## Steel Upon Steel

This condition prevails in the modern ball or roller bearing. In other words, steel balls or rollers, in rolling contact with outer and inner races of the same metal.

When the ball or roller bearing was perfected and its application extended so widely in the automotive field and on many types of industrial and railway units, it was predicated on the fact that the bearing parts could be precision finished to permit of extremely high load-carrying ability. At the point or line of contact this may involve some 200,000 to 300,000 pounds per square inch. Under such conditions resistance to fatigue is most important. This is attained by using steel alloys of high load-carrying capacity, heat-treated to controlled hardness and then precision-finished so that in service as nearly perfect rolling will occur as possible. The lubricant under such conditions functions largely as a corrosion-preventive,—lubrication is a co-function.

Other auxiliary functions of the lubricant are to assist the seal in preventing water or dirt from coming in contact with the bearing surfaces; and, as a conductor of heat, to aid in cooling the bearing.

A free flowing lubricant at the prevailing operating temperatures will most nearly lead to the attainment of these objectives. By this we mean a grease or oil which will "train" readily with the rolling elements, yet channel sufficiently so that churning does not occur. Oil is the preferred lubricant where the bearing seals are sufficiently tight to prevent leakage. It is especially desirable with high operating speeds, or extremes of temperature.

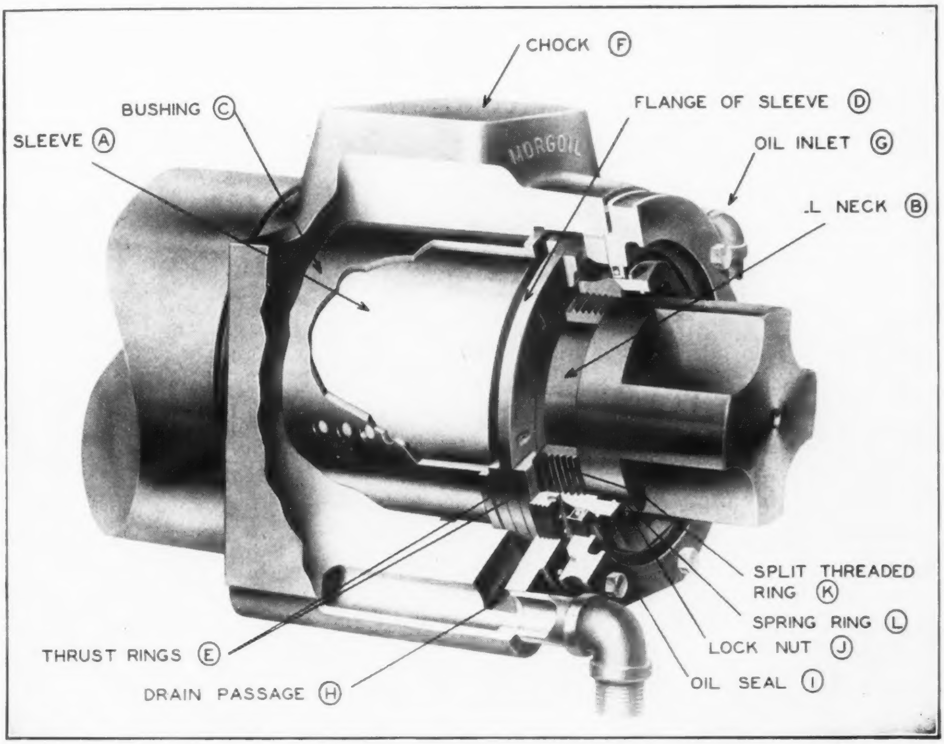
Churning will rarely be experienced with an oil, unless the oil is entirely too heavy. It is more likely to be experienced with a grease. Excessive churning will build up the torque through internal resistance within the lubricant itself. This frictional effect leads to heat development which may result in bearing temperatures beyond the cooling ability of the lubricant or the capacity of the external cooling system.

Provided that the lubricant is suited to the constructional and operating conditions, it can then most effectually protect the highly polished bearing surfaces if the seals are able to prevent entry of contaminants, or corrosive or abrasive materials.

A variety of seals have been developed including felt and cork washers or gaskets, metallic slingers, dust collars, expanding rawhide devices, grease-filled grooves, or various combinations of these. Proper sealing not only protects the bearing but also insures against premature failure of lubrication. Modern design leans more and more toward building a unit which will be immune to external conditions. The modern splash proof electric motor is typical of this idea. Here,

not only the bearings but also the windings are insured against entry of any type of foreign matter. Any leakage of lubricant in such a unit would obviously be to the detriment of not only the bearings but also the adjacent motor parts.

of design. These advantages still hold. Since their development, however, other types of seals have come into usage including metallic rings similar to piston rings, mercury baths in connection with vertical installations, and metallic springs for the purpose of maintaining




*Courtesy of Morgan Construction Company*

Fig. 8—The Morgoil Bearing. The alloy steel Sleeve A which is ground to a mirror finish fits over and is keyed to the tapered roll neck B, and becomes the journal of the bearing. Bushing C forms the opposed bearing surface. Lubrication is maintained by oil under pressure through oil inlet G. This same oil gives flood lubrication of the thrust bearing. Oil leaves the bearing assembly via drain passage H for recirculation. The entire assembly is enclosed in a cast steel chock F. Note oil inlet G and outlet H are drilled in this chock.

In this development, high temperatures also had to be considered. The effect of high temperature is to reduce the viscosity or consistency of any lubricant. The extent to which this will occur depends, of course, upon the original body of the product. Unless the latter is of the nature of steam cylinder oil with a viscosity in the neighborhood of 130 seconds Saybolt or above, at 210 degrees Fahr., considerable leakage may result from certain types of bearings at temperatures much above 175 degrees. For this reason, steam cylinder stocks are used in certain grades of high temperature ball and roller bearing greases. With a lubricant of this nature plus a suitable bearing seal, leakage, even under extreme temperatures, can be effectively prevented.

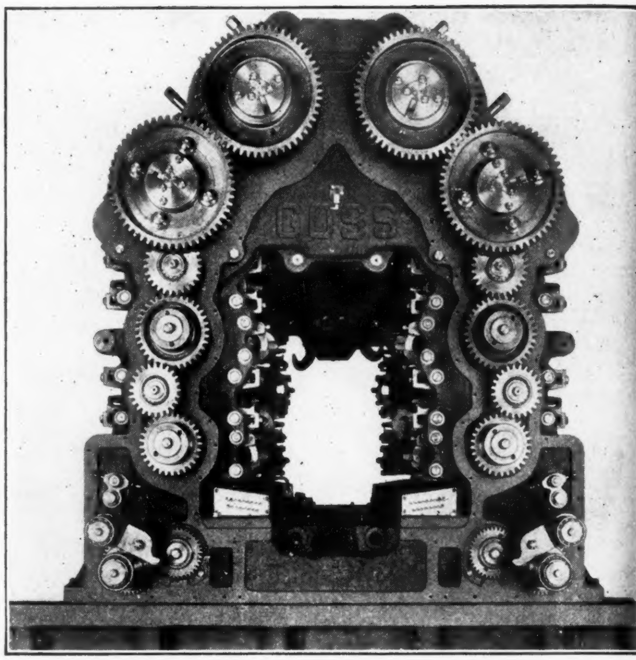
When bearing sealing was first considered, felt and leather washer and grease-groove seals were preferred due to low cost and simplicity the adjustment of felt, leather, rawhide and cork with respect to the rotating element. Composition rings have also proved of value as an oil seal, or to protect a grease-lubricated bearing against entry of water. Vertical installations have called for considerable study of sealing devices.

## Wear Must Be Low

The most effective bearing seal must not only seal, but also must show practically no wear in service; otherwise, the purpose may be more or less defeated. Washer type seals may consequently be unsatisfactory, although the rate of wear will depend upon the quality of the material. This is why adjusting springs are used today in connection with washer or leather cup seals in order to keep the material in close contact with the shaft or journal surface, and thereby compensate for wear and

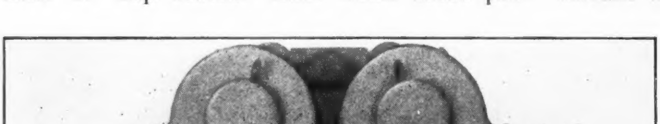
enable dependable retention of lubricant.

Grease groove seals are used to prevent leakage of lighter lubricants. They are relatively simple and inexpensive to design. They must be periodically examined, however, in case the sealing grease requires renewal, otherwise, possible glazing of the surface of this latter where it comes in contact with the rotating shaft might result in sufficient clearance to allow leakage of the bearing lubricant. Very heavy bodied greases of high melting point are adaptable to service as grease seals, provided they show no tendency to separate oil from soap, and contain no material which might be abrasive to the shaft surface. Grease grooves can also be used together with felt washers, in certain types of service, although this may require extension of the length of the bearing housing.



*Courtesy of The Goss Printing Press Company*
Fig. 10—Exposed view of the gearing on a Goss newspress showing perfection of fit, which requires careful lubrication. The oil reservoir of the circulating system is located at the lower right side of the base.

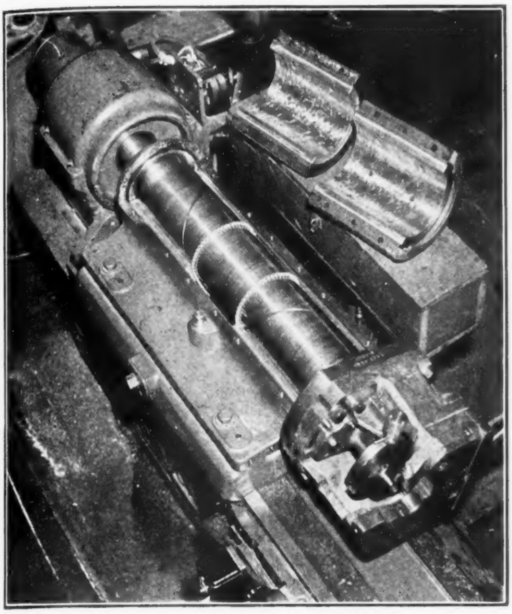
Many authorities, however, feel that the spring adjusted seal insures the most uniform contact and conformation with the surface of the shaft. It is extensively applied to rawhide or cup leather seals when most positive sealing is essential and where first cost should be of secondary consideration. This type of seal is well suited to the ball or roller bearing, where use of a minimum amount of housing space is advantageous. It is an especially good seal in the presence of moisture, also where abrasive dust or metallic particles must be kept out of the bearings.



*Courtesy of The Goss Printing Press Company*
Fig. 9—The operating side of a Goss newspress equipped for automatic lubrication. Note the closures and oil piping for oil circulation.

## Analysis of Operating Conditions

The selection of petroleum products for process work in the manufacture of any type of machinery and later, for lubrication throughout the operating life has become a major factor in maintenance. With the perfection of specialized petroleum lubricants it has definitely associated the petroleum chemist with the lubricating engineer and machine designer. Operating machinery may present certain very definite problems according to the speed, load and temperature conditions. At times these may be most extreme, as in stratasphere flying where sub-zero temperatures as low as minus 75 degrees Fahr. may be experienced. This presents



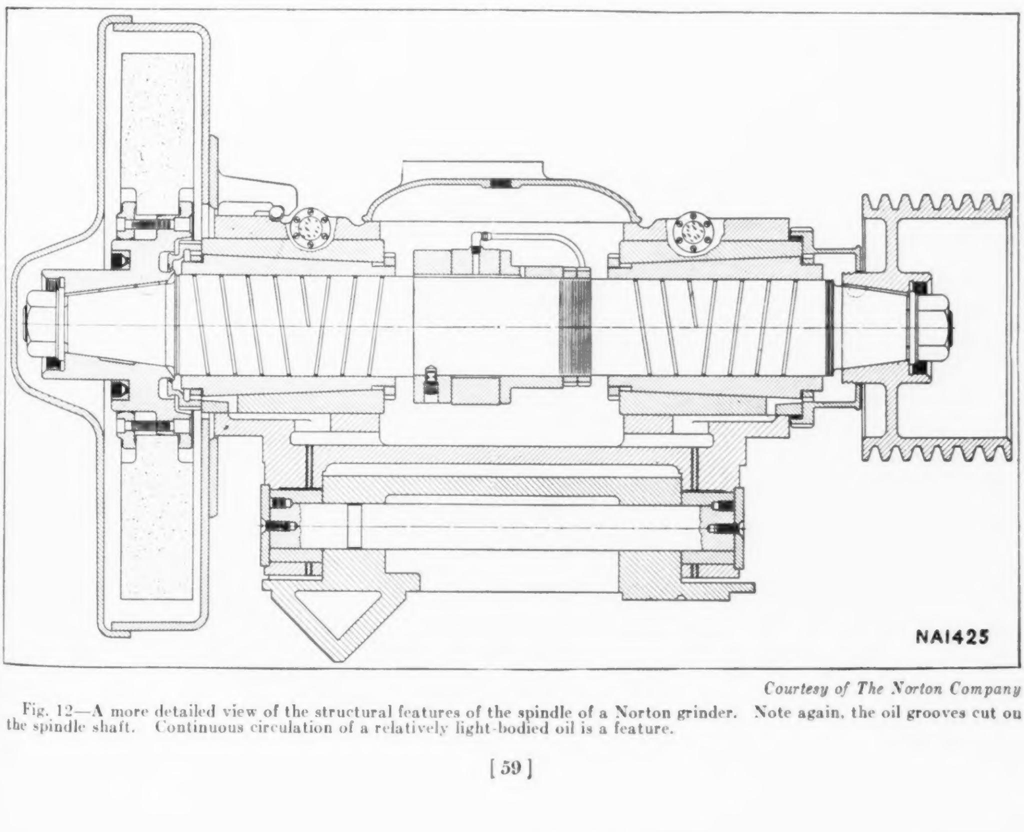
*Courtesy of The Norton Company*

Fig. 11—Exposed view of the spindle of a Norton grinder. Note especially that there are no oil grooves in the bearing caps, oil circulation being maintained by the grooves cut on the spindle shaft.

ed a most important problem to the petroleum chemist, for he had to develop a type of grease which would enable ball bearings to turn without excessive drag, otherwise aircraft controls, landing gear or bomb releases might become inoperative. The solution to the problem has been approached by the closest cooperation between the bearing designers and specialists in the petroleum industry.

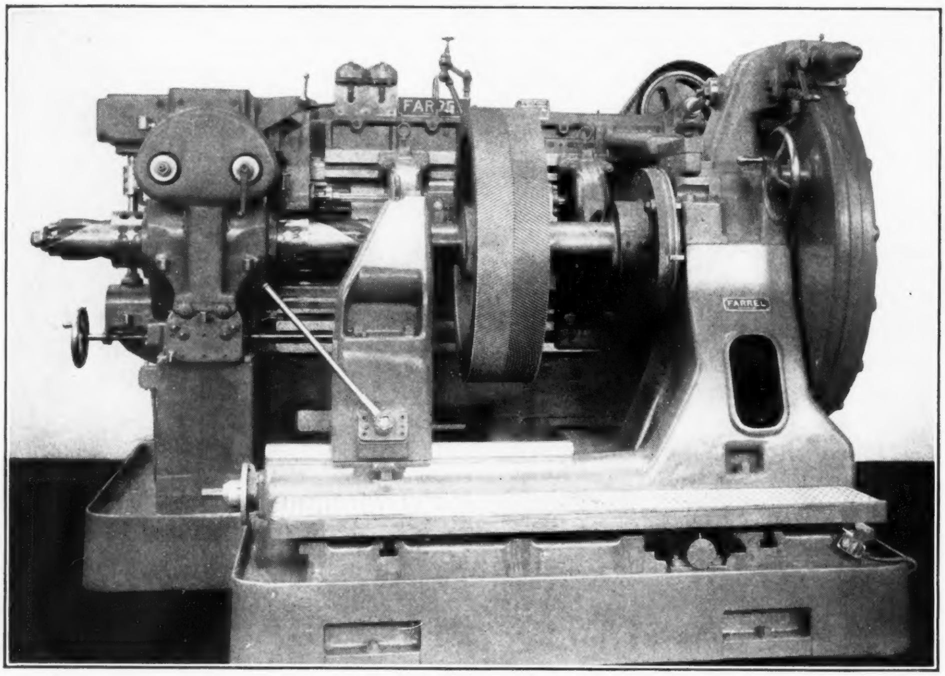
Speed presents another typical example, when higher and higher speeds were required it was necessary for all concerned to look into the practicability of reducing bearing clearances, to study the film strength characteristics of a variety of lubricants and investigate the feasibility of going to thin oil films to enable more positive circulation of the lubricant through the clearance spaces.

This cooperative research has been of decided benefit to the maintenance engineer. As more perfected means for lubricant application have been developed, his worries regarding machine protection have been decreased. The more automatic the lubricating system the better the protection. This permits the maintenance engineer to study the extent to which production schedules can be met with available machinery, it also permits him to predict the extent to which the structural features of his machinery will withstand the increased loads which may be developed under full-time production.




*Courtesy of The Norton Company*

Fig. 12—A more detailed view of the structural features of the spindle of a Norton grinder. Note again, the oil grooves cut on the spindle shaft. Continuous circulation of a relatively light-bodied oil is a feature.



*Courtesy of Farrel-Birmingham Company, Inc.*

Fig. 13—Front view of a Farrel-Sykes gear generator showing a gear on which the teeth have just been cut. Features of this machine are the provisions for automatic lubrication by force-feed oil circulation or pressure gun greasing, according to the location and function of the operating parts.

The lubricating engineer can be the most helpful in extending advice as to lubricants which should be used when such changes are made. Normally he can draw on experience covering a wider variety of operating conditions than the plant personnel, since he must cover all industries in his daily work. This is why lubricating engineering service is so widely recommended; it can be one of the greatest benefits to the operator of mass production machinery.

## CONCLUSION

The advances which have been made in machine design have contributed in no small measure towards the productive efficiency of our modern industrial machinery. More recently the ingenuity of the designing engineer has enabled the remarkable conversion of much of this machinery from peace-time production to the development of military equipment. Yet, to repeat the thought expressed in the introduction to this article—the modern production line could not have been perfected had not the petroleum industry kept pace by developing improved lubricants which would function under operating conditions which seemed continually to become more exacting. The laboratory of the petroleum chemist has become as important as the drawing board of the machine designer.

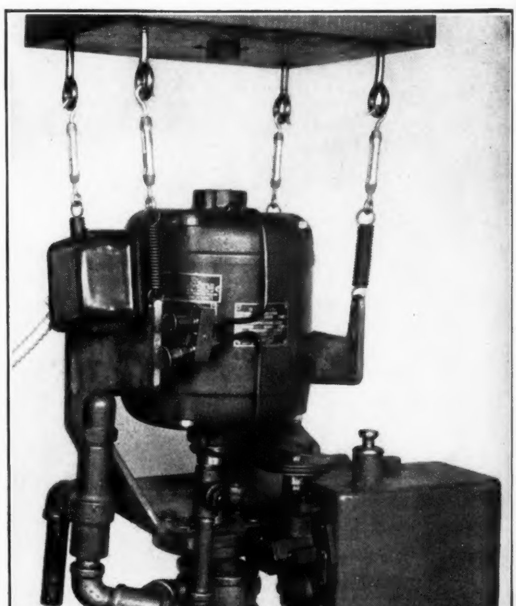


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Fig. 14—The motor driven oil pump assembly for a Norton grinder showing the method of spring suspension to enable smooth operation. Note belt drive from the motor to the oil pump, also grease lubrication cups and piping for the motor bearings.



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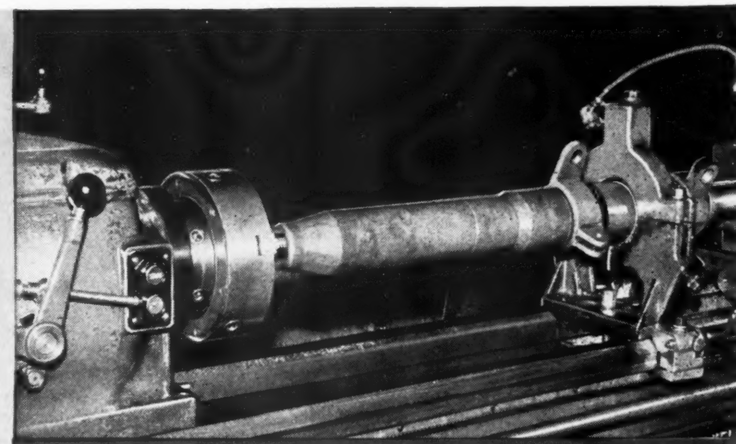

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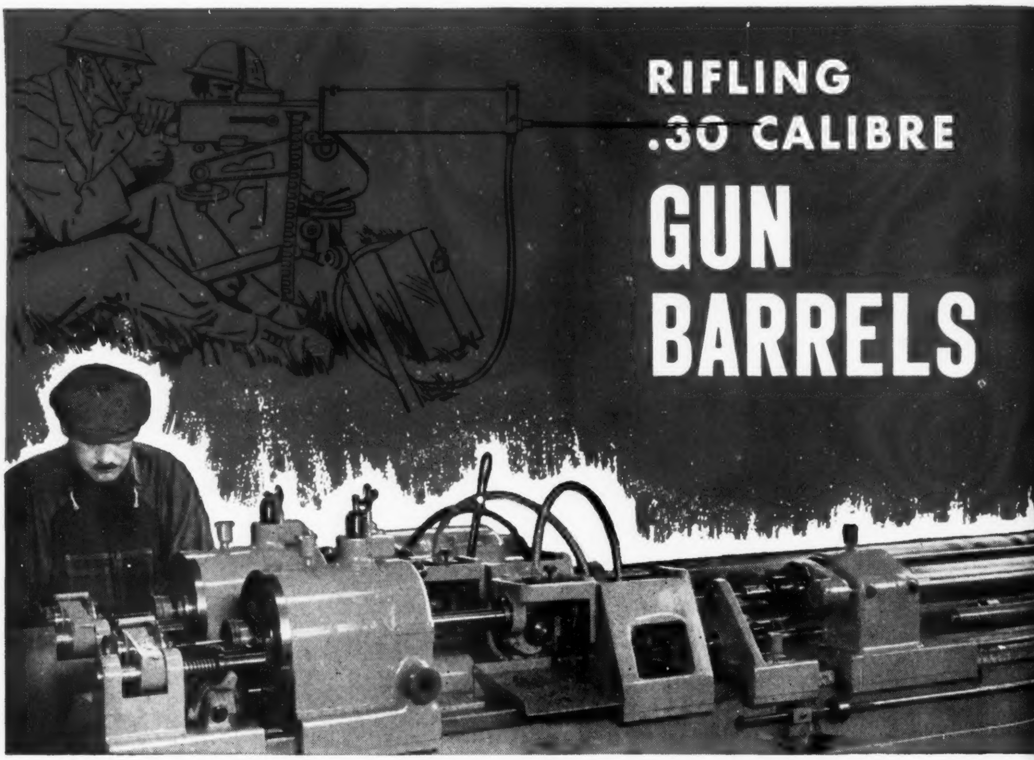


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